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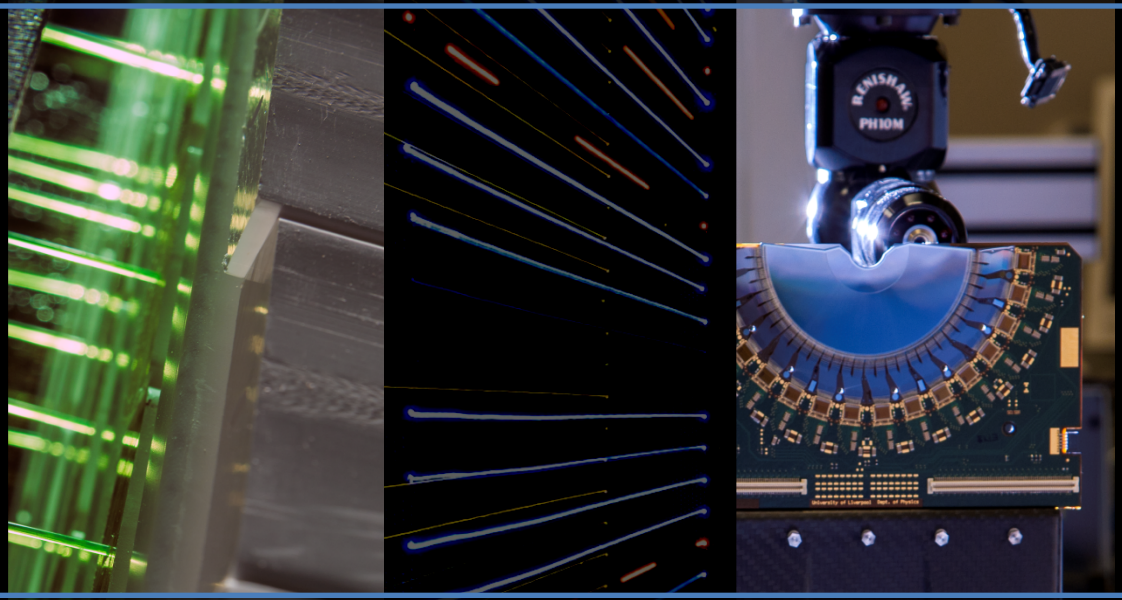
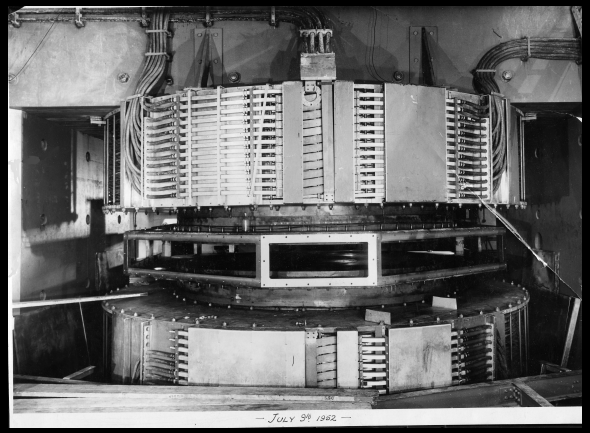
pEDM Collaboration Meeting



Themis Bowcock

Particle Physics



Barkla
Chadwick
Rotblat

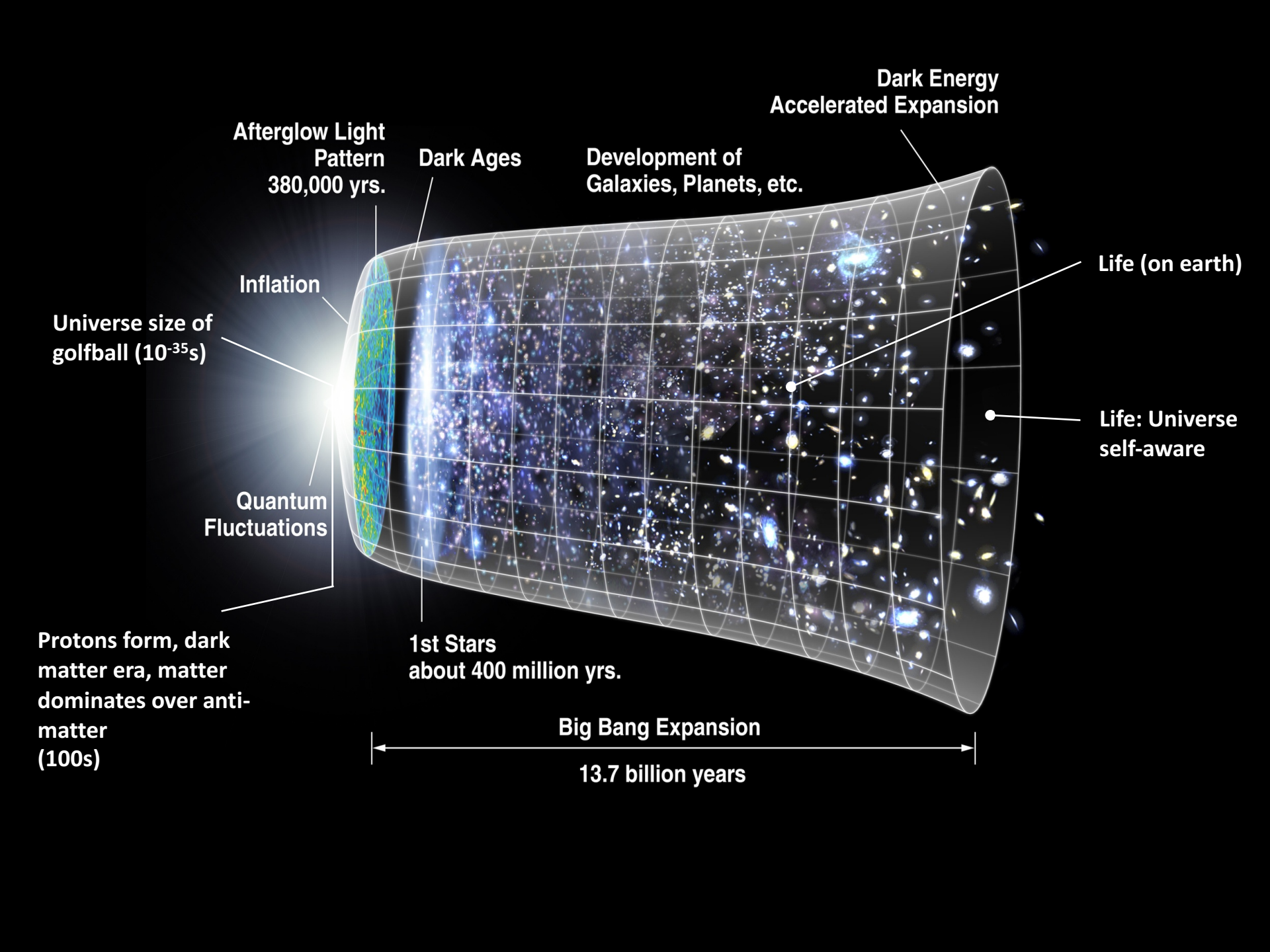
Physics @ Liverpool

Largest Particle Physics Group in UK – by supported staff & grant

Top grant earner (by almost a factor 2)

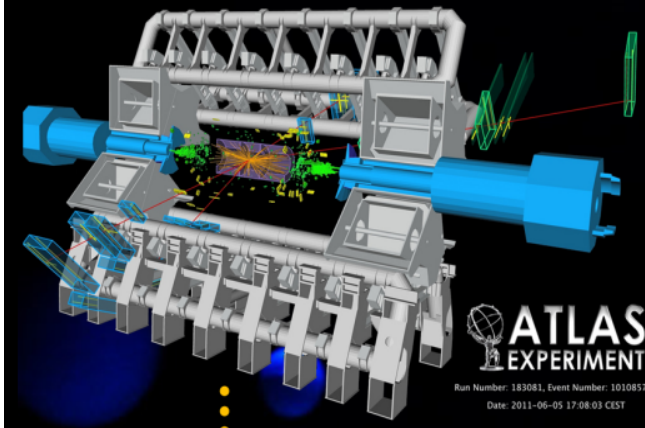
Unique Facilities

- LSDC & Detector Fabrication Facility
- Advanced Materials Lab


Dark Energy
Accelerated Expansion
Afterglow Light
Pattern
380,000 yrs.
Dark Ages
Development of
Galaxies, Planets, etc.
Life (on earth)
Inflation
Universe size of
golfball (10^{-35}s)
Life: Universe
self-aware
Quantum
Fluctuations
Protons form, dark
matter era, matter
dominates over anti-
matter
(100s)
1st Stars
about 400 million yrs.
Big Bang Expansion
13.7 billion years

What happened before?

2014



Neutrinos: LBNE, SNO+, HK, T2K

probing the new physics of neutrinos and their properties.

Themis Bowcock

Precision Frontier: LHCb, NA62, g-2

Searching for new physics with quarks, leptons, hadrons and tests of the Standard Model.

The Energy Frontier: ATLAS

studying Higgs, searching for direct evidence of new Physics and testing the Standard Model and developing new technologies.

Phil Allport

Max Klein

Christos Touramanis

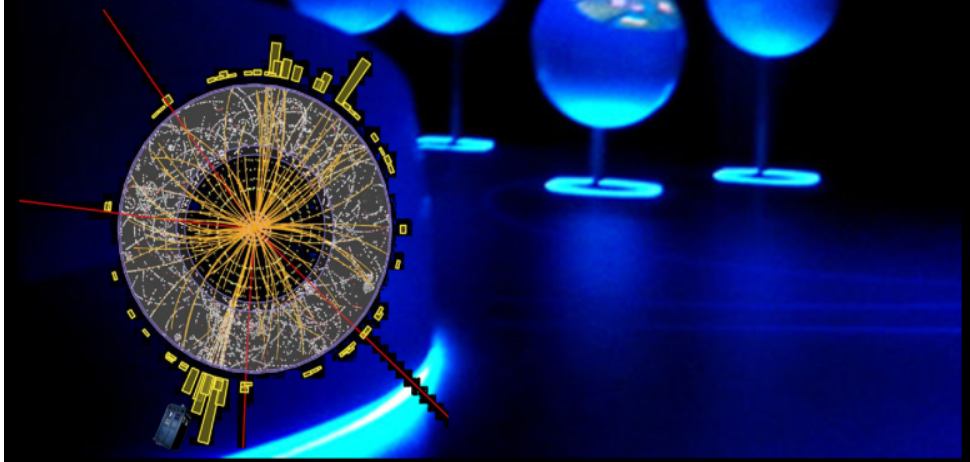
Tara Shears

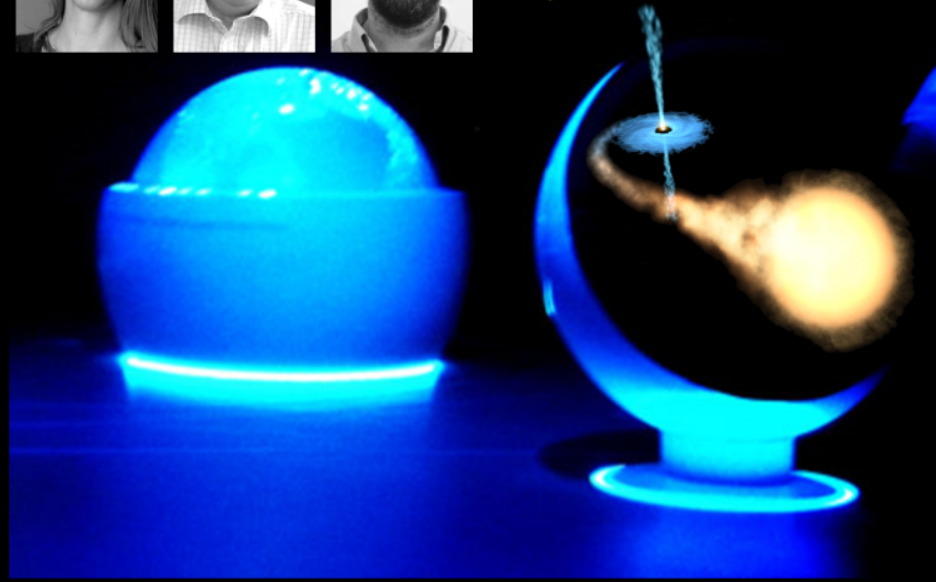
John Dainton

Tim Greenshaw

Particle Astrophysics: CTA

exploring the observable universe for high energy phenomena.





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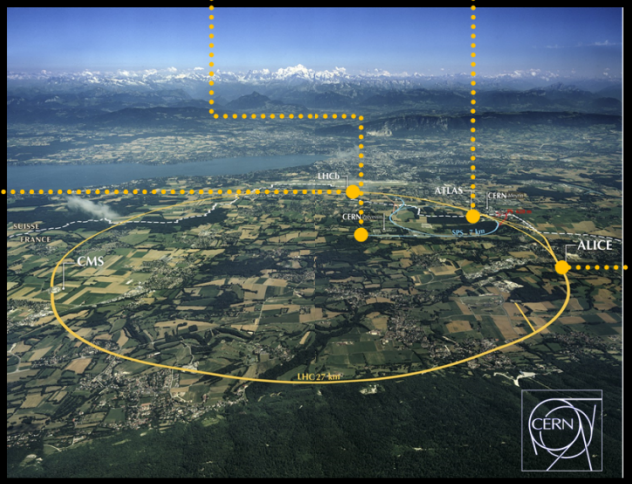
Physics on Three Continents

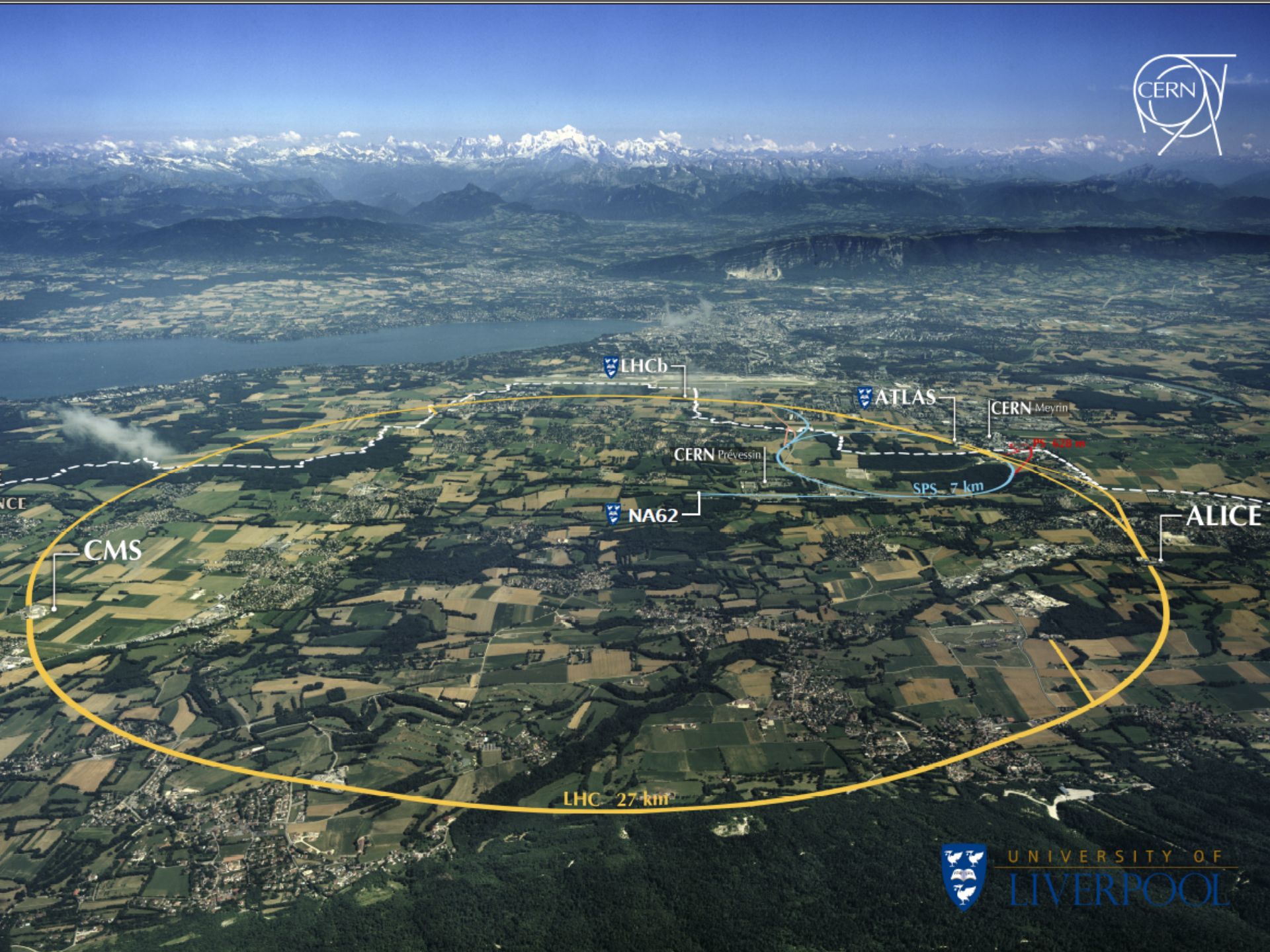


The CERN site (right) just outside of Geneva, Switzerland hosts the largest scientific pieces of equipment in the world. The LHC ring is 27km in circumference.

Experiments at a glance

We conduct experiments in Europe, North America and Asia. These are selected to attack the most critical and important physics questions. The time scale for most of our experiments runs into years and even decades which involves high degree of forward planning. **CERN** remains our most important host laboratory, with over 60% of our staff involved in experiments there.

The location of our main experiments is shown above. Our flagship experiment, **ATLAS**, has over 20 academics, engineers and students. working on it and is expected to run until about 2035.


CERN
LHCb
ATLAS
CERN Meyrin
PS 628 m
CERN Prévessin
SPS 7 km
NA62
CMS
ALICE
LHC 27 km
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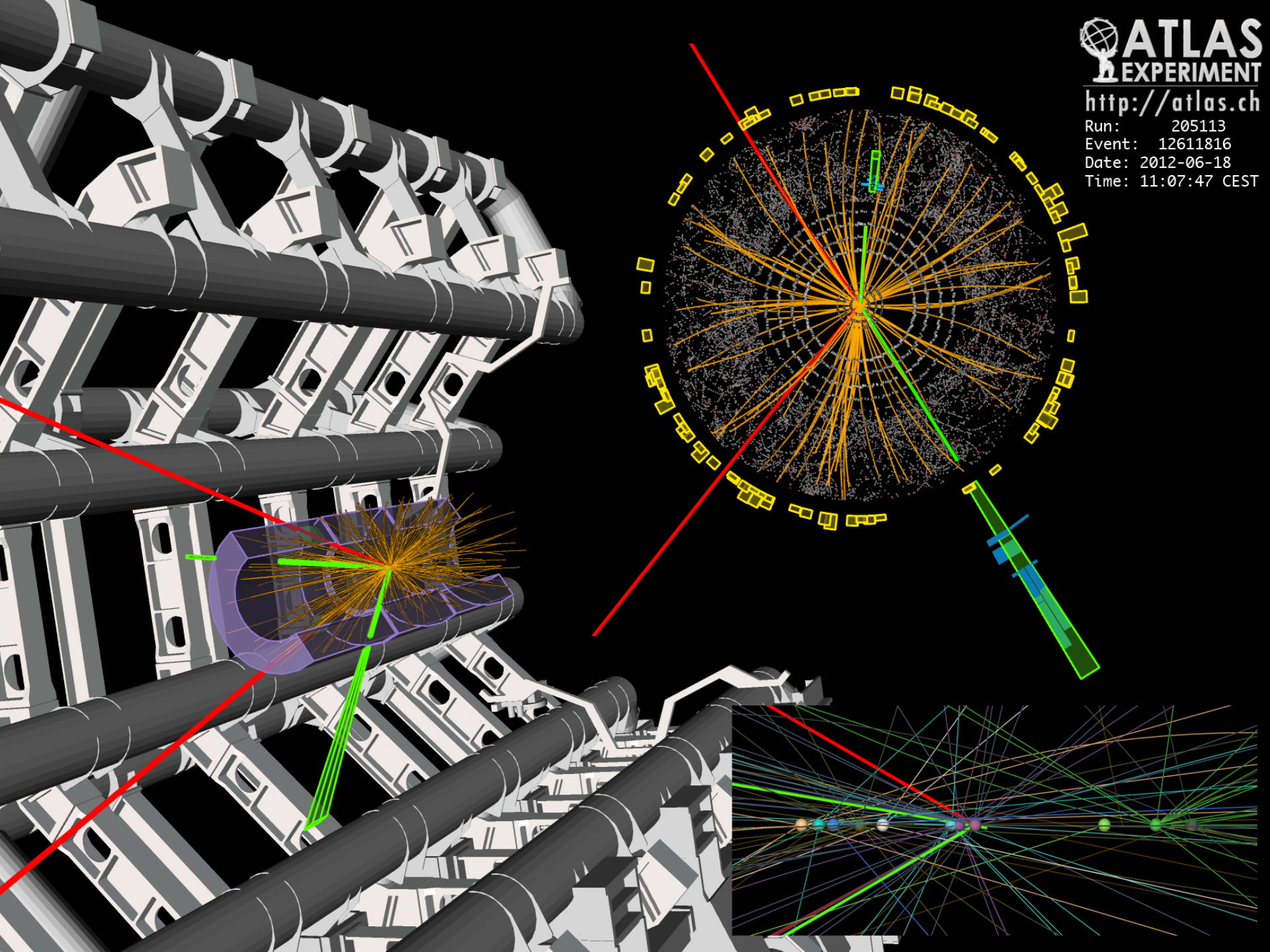
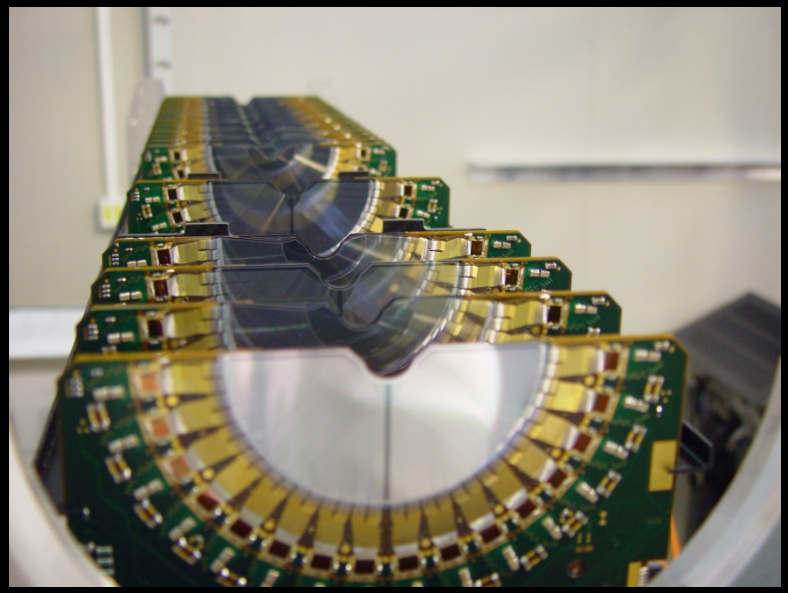
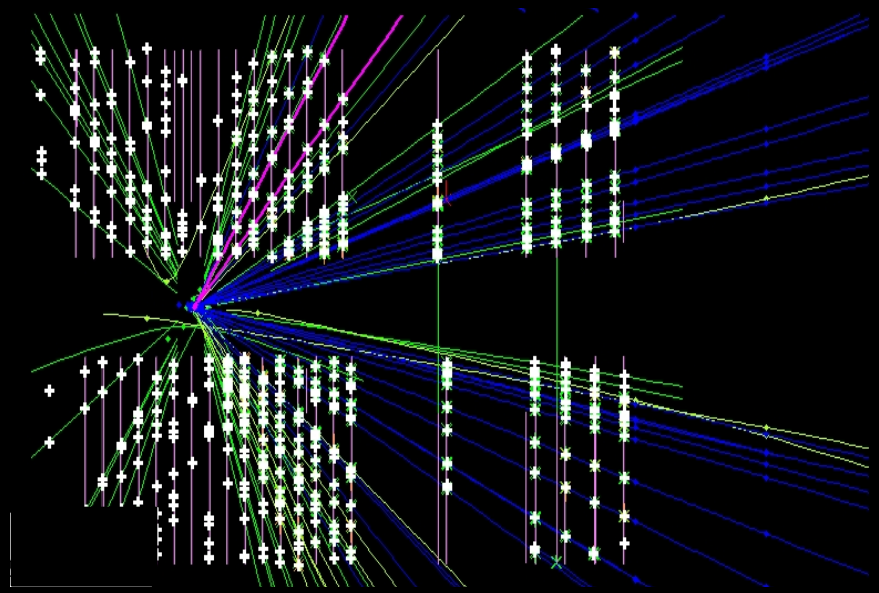

ATLAS
EXPERIMENT
http://atlas.ch
Run: 205113
Event: 12611816
Date: 2012-06-18
Time: 11:07:47 CEST

LHCb





VELO designed and built in UK ~ 100 person-years

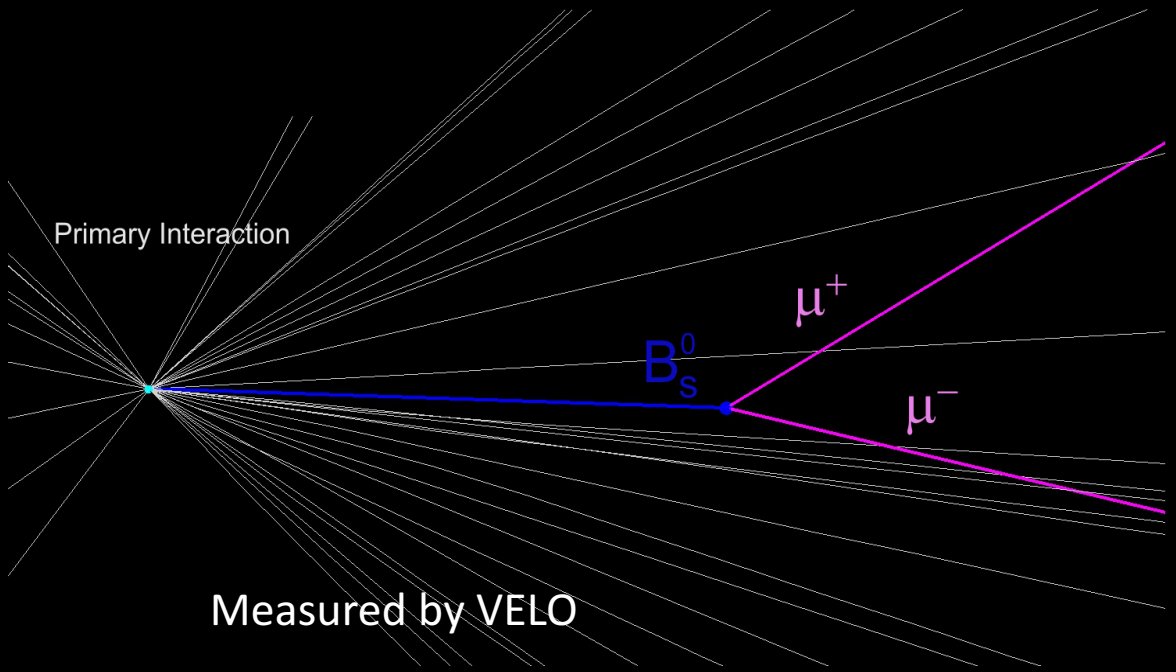
Operates about 7mm from beam
Main tracking detector
Resolution down to ~4microns

Measure lifetimes down to ~30fs

30 / (1,000,000,000,000,000) s

LHCb

- matter-antimatter asymmetry

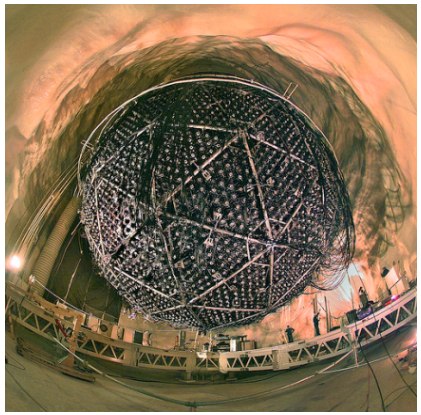


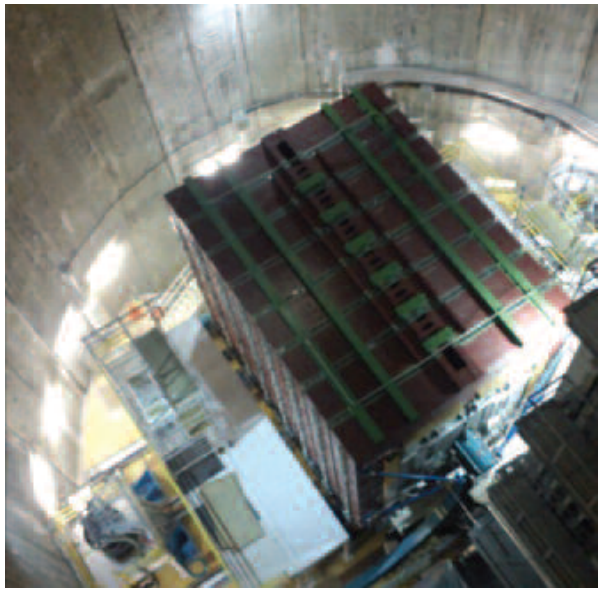
- not enough….

Neutrinos

- The reclusive particle and a window to the early Universe
- Travel for a year through lead without stopping!
- Masses not understood (very light)
- Are they the source of matter-antimatter asymmetry?

Neutrinos





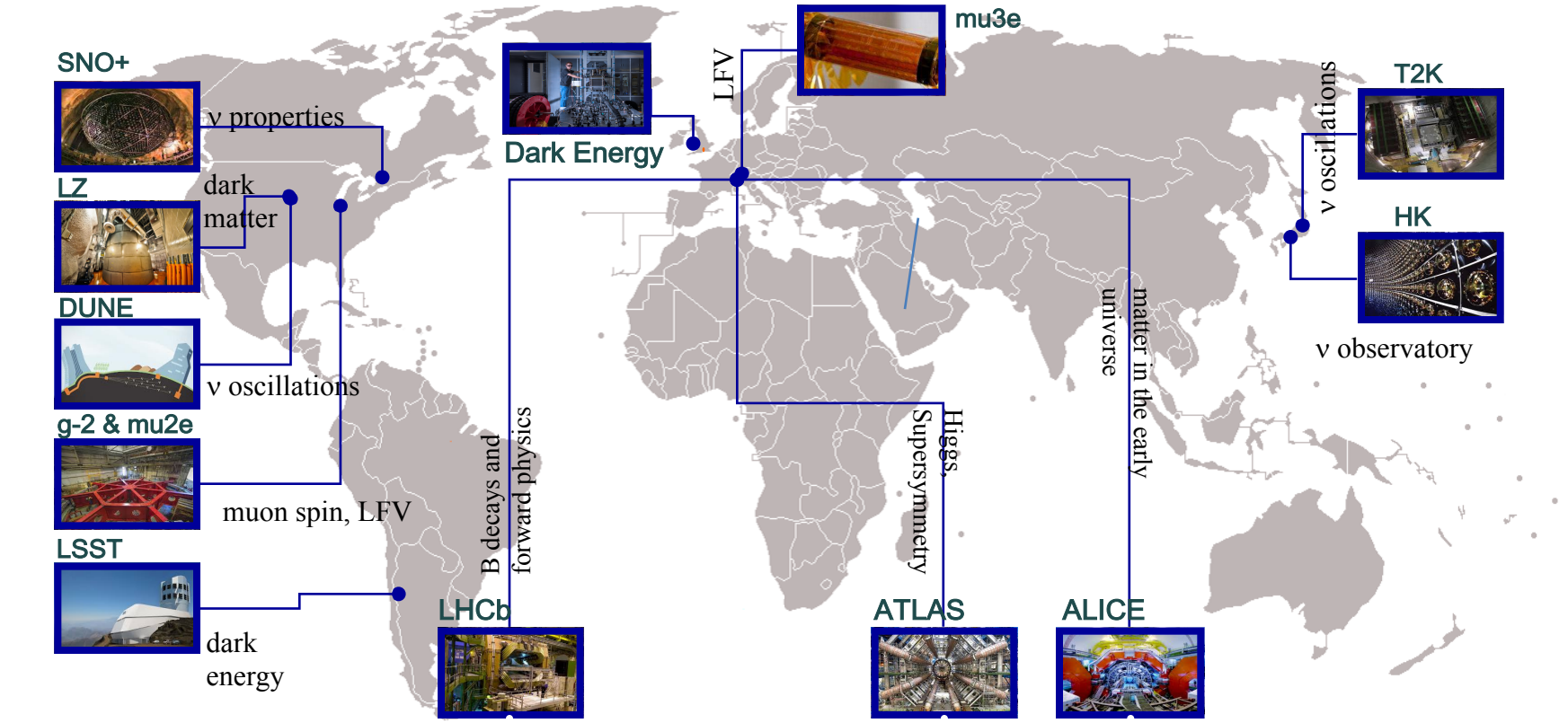
Detectors in North America and Asia

2014-2018: New ways of provisioning physics

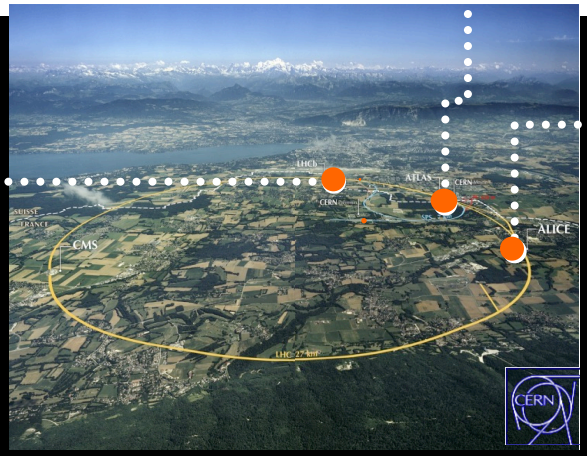
- lepton flavour violation (mu2e, mu3e)
- dipole moments (muon, pEDM @ CERN)

- LSST — DE/DM
- MAGIS-100 — DM/gravitational waves

- Space Based Experients

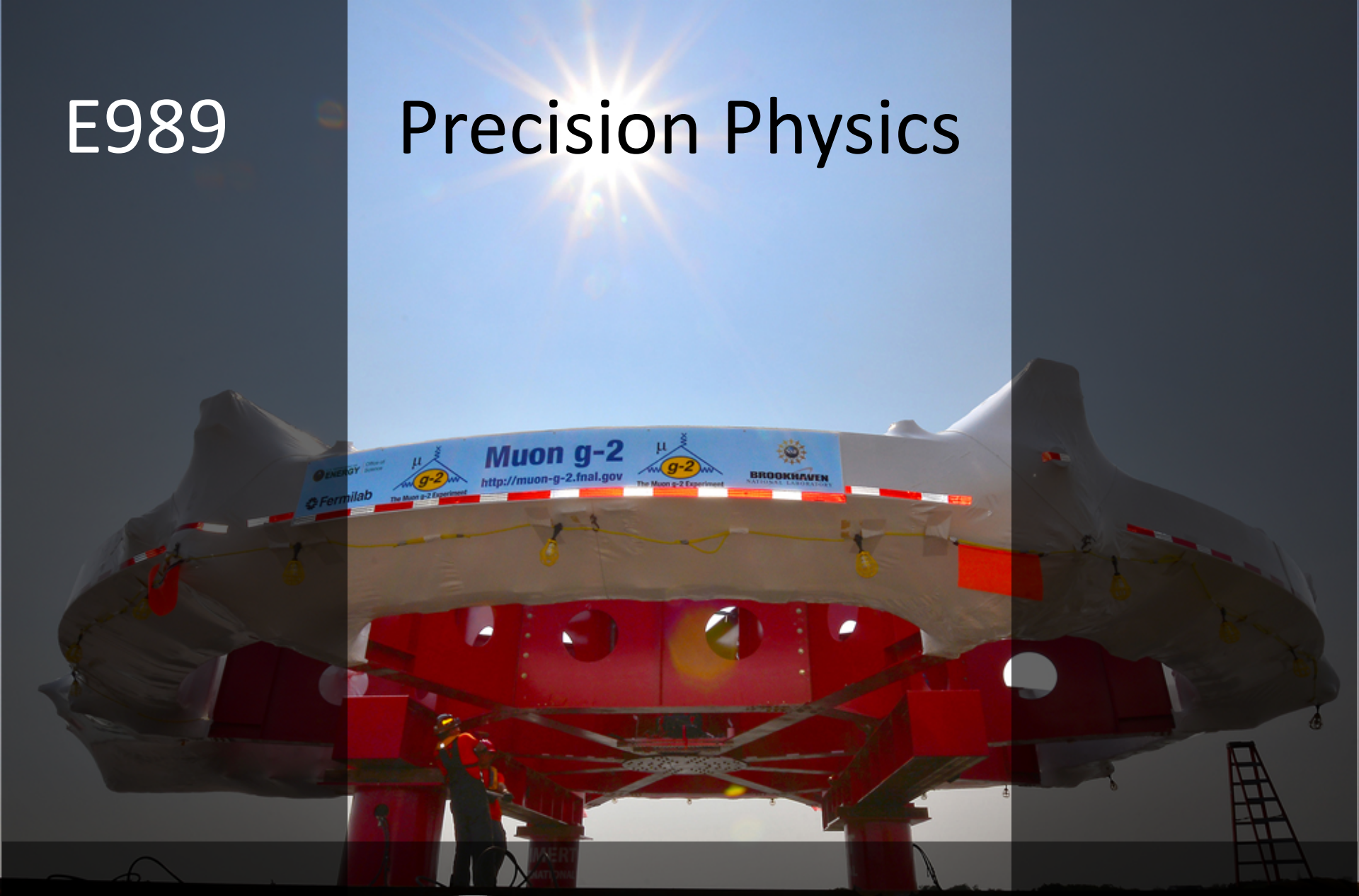


Physics on Four Continents



Experiments at a glance

E989 Precision Physics



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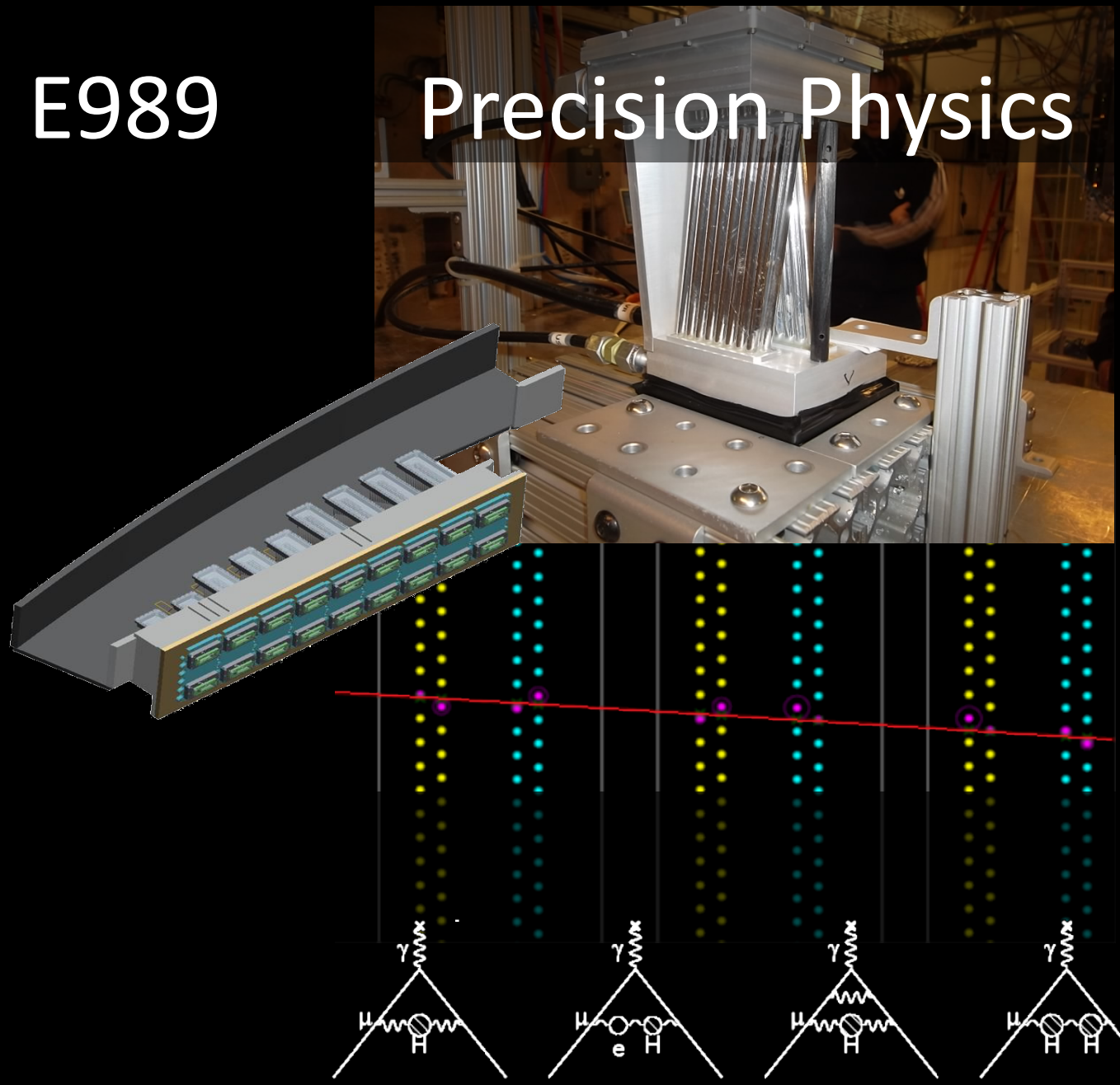
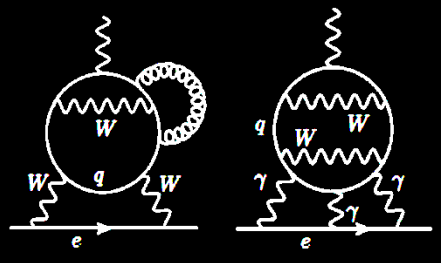
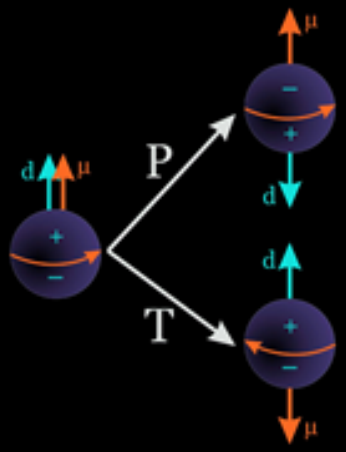
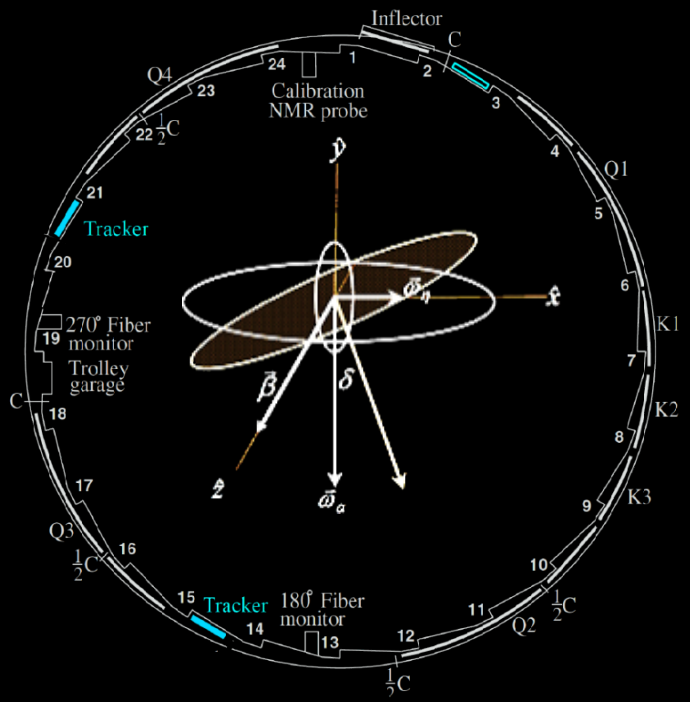
E989 Precision Physics

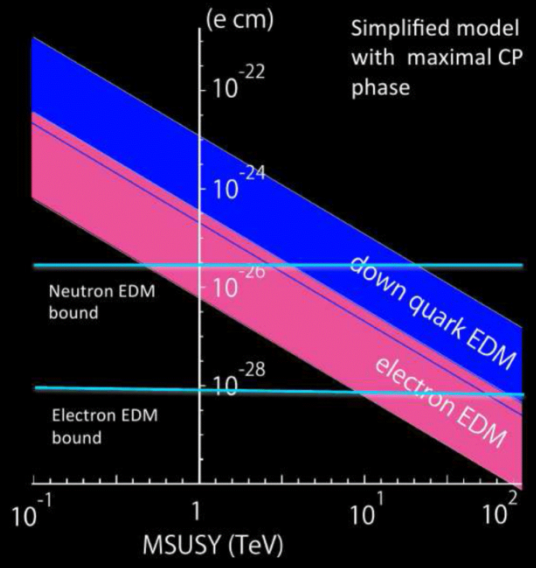


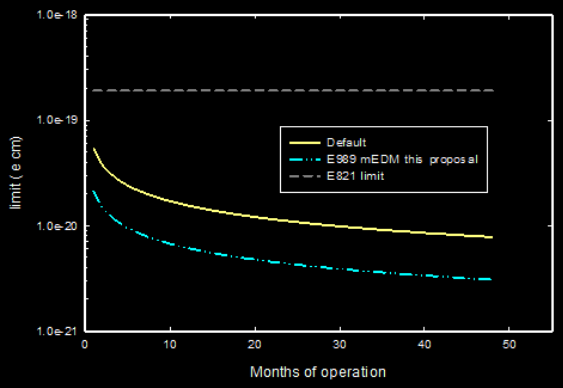
E989 Precision Physics mEDM





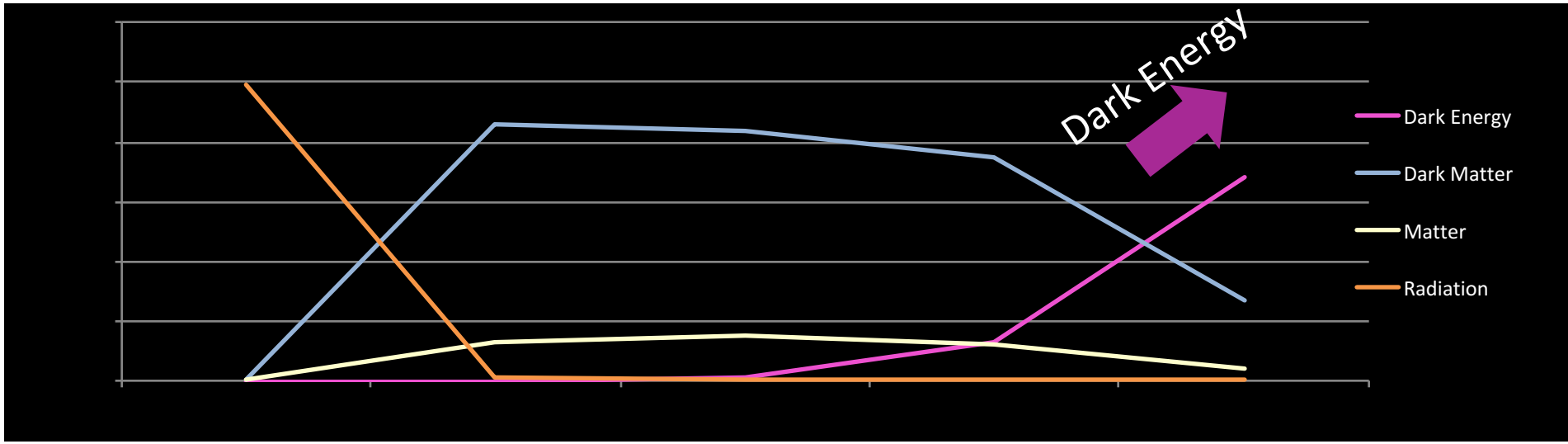




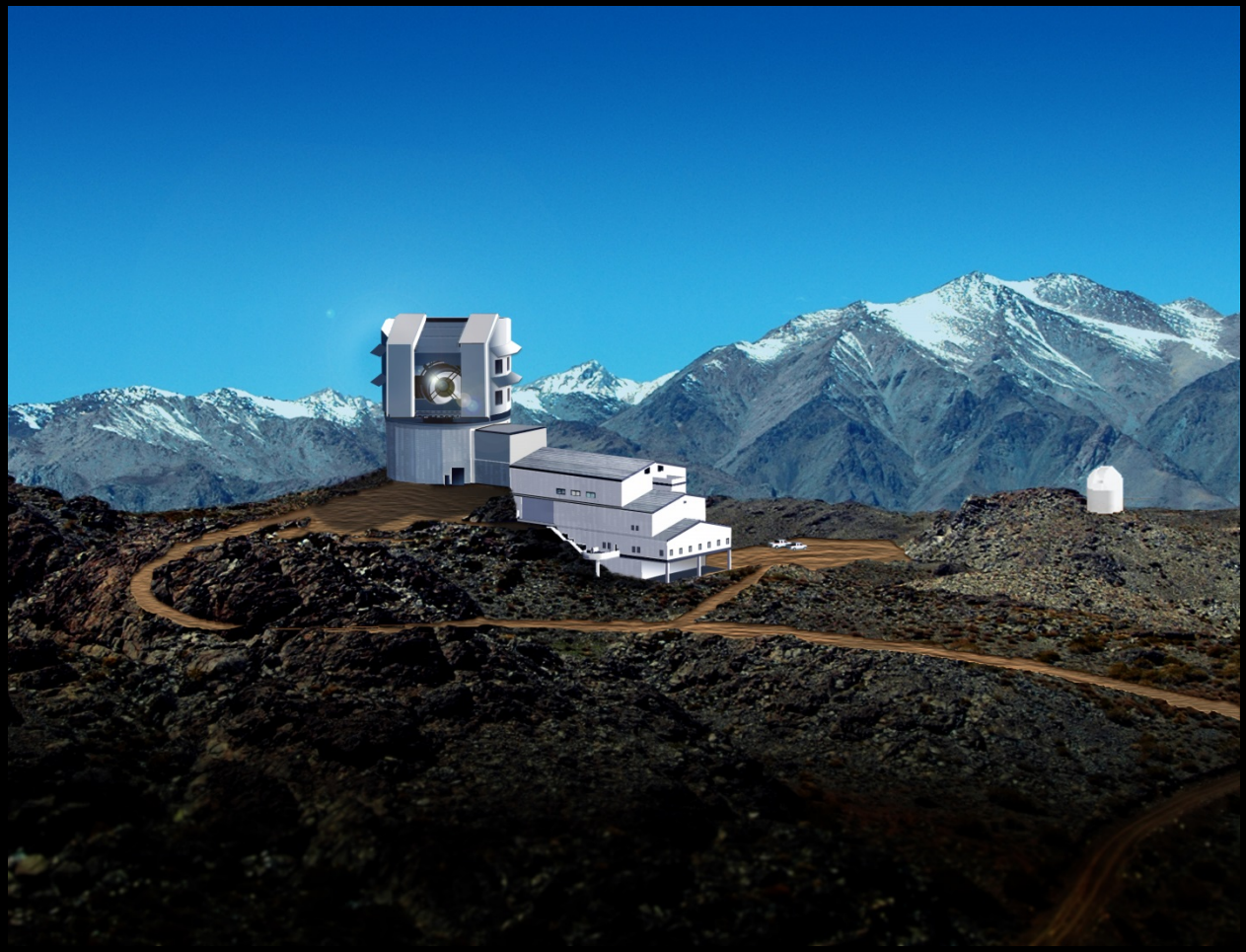


Request to EU for funding (2015)


A History Shaped by Dark Forces
Dark matter
Dark energy
The big bang
13.8 billion years ago
Our universe blossoms from a hot, dense state smaller than an atom. Within milliseconds it inflates enormously.
Dark matter forms
First seconds of the universe
Dark matter also emerges in the first second. Interacting with particles of normal matter only through gravity, it begins to pull them together.
Stars light up
100 million years after the big bang
Clouds of hydrogen assembled by the gravity of dark matter collapse to form the first scattered stars. Nuclear fusion inside them creates heavier elements—and lights space.
The expansion slows
1 billion years after the big bang
Stars clump into galaxies, galaxies into clusters along a scaffolding of dark matter. The mass of all matter, most of it dark, is so great that its gravity slows cosmic expansion.
Dark energy rises
4-8 billion years after the big bang
After slowing for billions of years, the expansion accelerates again. Why? A mysterious repulsive force, dubbed dark energy, has begun to counteract the pull of dark matter.
Ever outward
Today
The universe hurtles outward toward an uncertain future.
Composition of the universe
Dark energy <1%
Dark matter <1%
Matter <1%
Radiation 99%*
86%
<1%
<1%
13%
84%
1%
<1%
15%
75%
13%
<1%
12%
Dark energy 68%
Dark matter 27%
Radiation <1%
Matter 4%
*Percentages do not add up to 100 due to rounding.


Dark Energy
Dark Energy
Dark Matter
Matter
Radiation

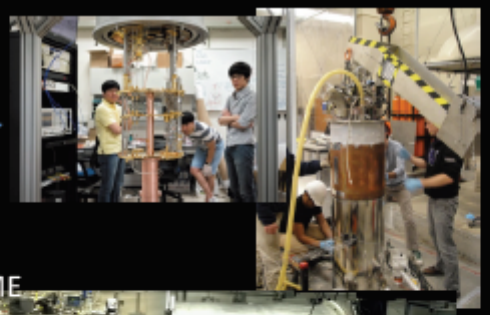
New Experiment: LSST

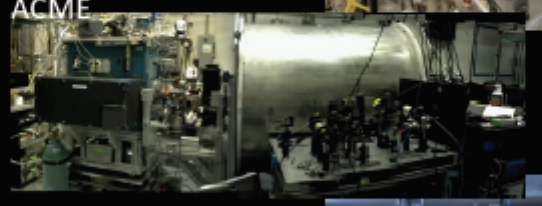


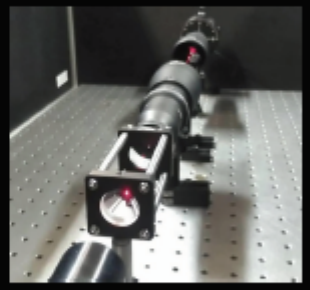
Smaller & Table Top Expts. Searching for fundamental physics …

Theory and advances in technology and new ideas permit new ways to probe Universe(examples)

- Axion searches (@CAPP,ADMX)
- Ultra precise EDM tests (electron, muons, nucleons)
- Precision Gravity (new forces) – Cold Atoms
- Towards Relic Neutrinos (e.g. Tritium)
- Probing Quantum Foam



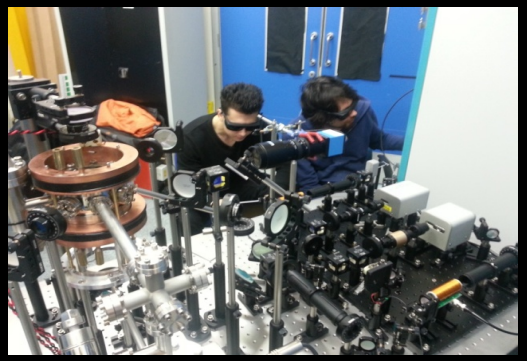




These smaller experiments involve new thinking and new expertise they should be encouraged and supported

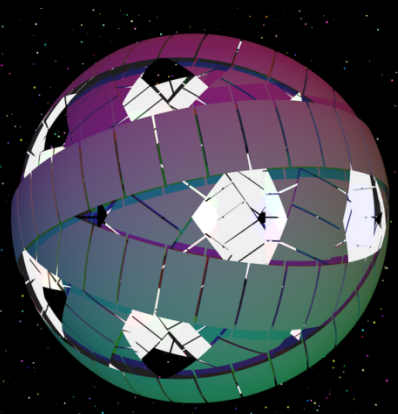
New Frontiers

Dark Energy



Precision / EDM

Instrumentation: The Great Enabler



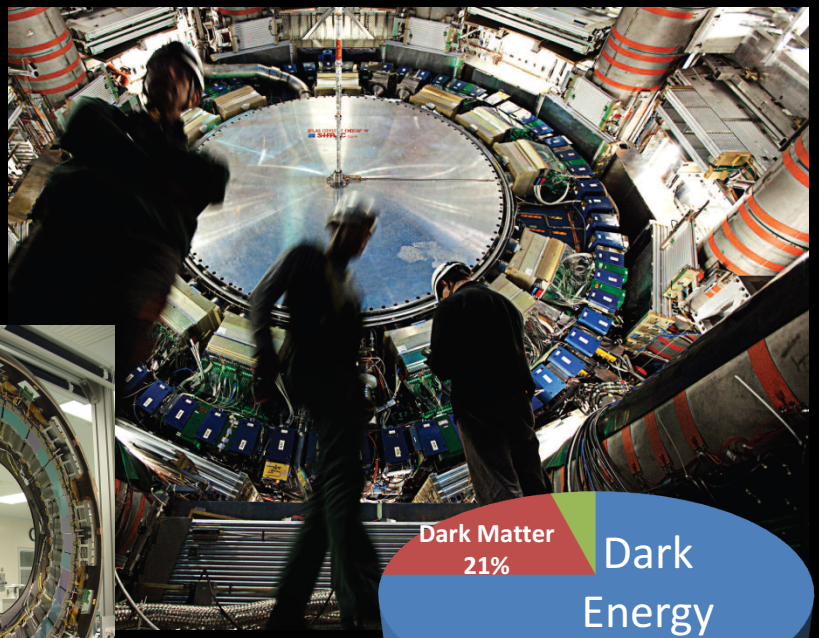
"New directions in science are launched by new tools much more often than by new concepts.

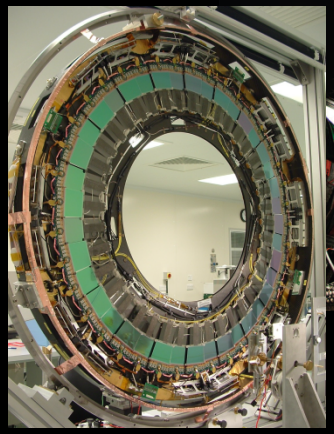
The effect of a concept-driven revolution is to explain old things in new ways. The effect of a tool-driven revolution is to discover new things that have to be explained"

Freeman Dyson

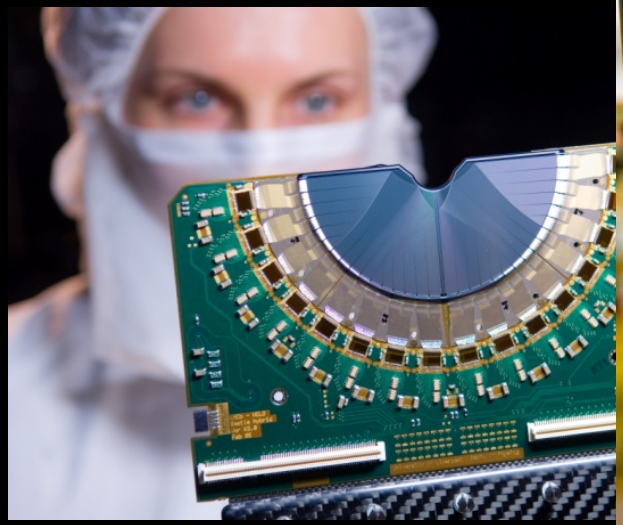
Discovery

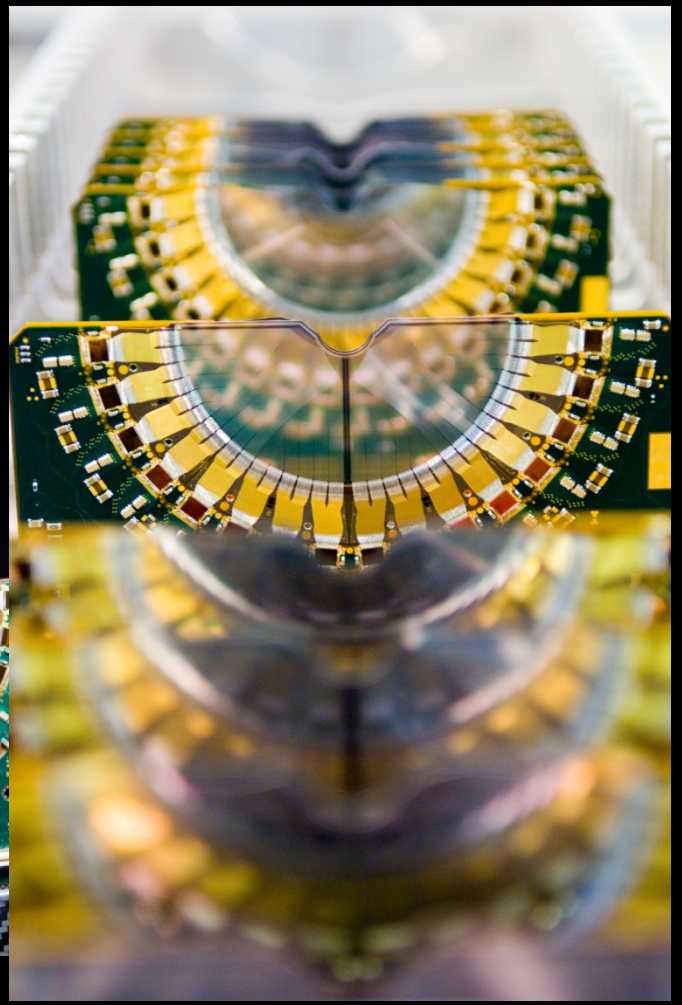
Looking for Dark Matter
Studying Matter- Anti Matter





"...95% of the Universe is made of Energy and Matter we know nothing about

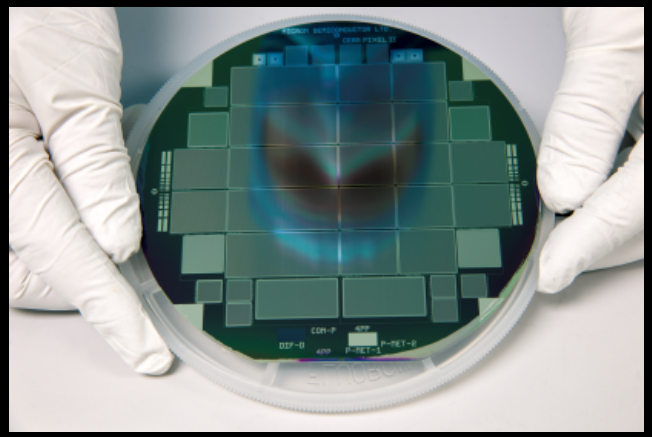


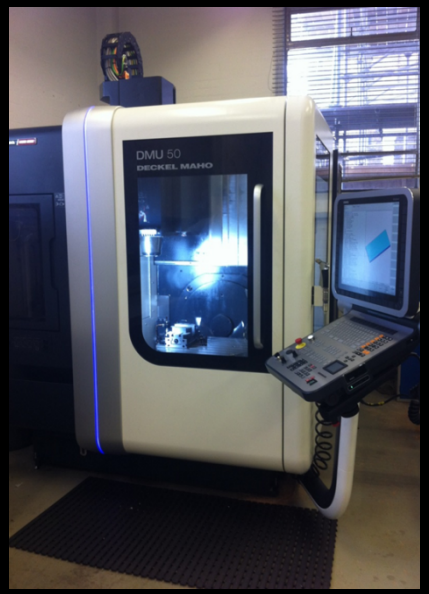


Facilities

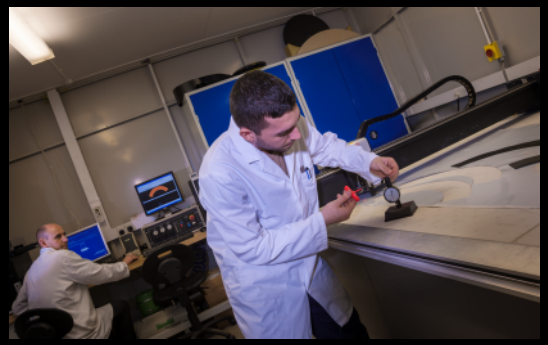
- Advanced Materials Lab
  - Composites for LHC
  - Upgrades ATLAS, ALICE

Liverpool Semiconductor Detector Centre





Detector Manufacturing Facility



Advanced Materials Laboratory

Detector Development (Si)

- Silicon
  - RD50
  - ATLAS
  - LHCb
- New Technologies
  - Hybrid pixels
  - HV-CMOS
  - Live-”emulsion”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Particle Physics


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Manufacturing Technology Centre
sigmatex
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chael Head


RENISHAW
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TYGAVAC
mtc
sigmatex

Building

Sensor City

Quantum Physics for Fundamental Science

UNIVERSITY OF LIVERPOOL

Cockcroft Accelerator Institute

- Initiated by Liverpool
  - New director (2014)
- Resource for investment in from STFC

UK Groups we work closely with…

Cockcroft Institute

- UCL
- Manchester
- Oxford

Connections: Quarks to the Cosmos

There is a compelling and exciting future.

We will continue to reveal a cosmos more wonderful than we can imagine

Playing a role in the journey of discovery is the aspiration of our field and a privilege to participate in

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DEPARTMENT of PHYSICS

Thanks for invitation …